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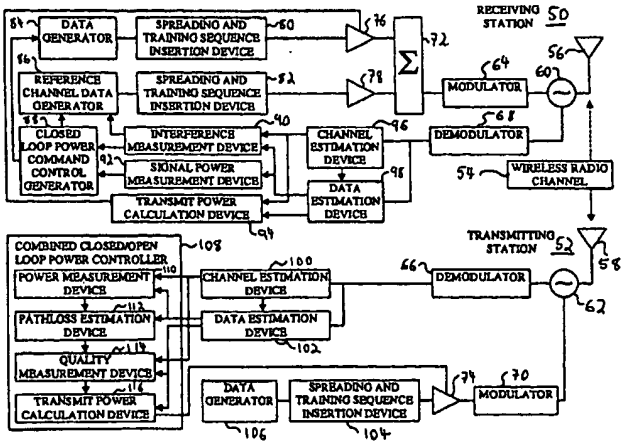

(57) Abstract

Combined closed loop/open loop power control controls transmission power levels in a spread spectrum time division duplex communication station. A first communication station (50) receives communications from a second communication station (52). The first station transmits power commands based on in part a reception quality of the received communications. The first station transmits a second communication having a transmission power level in a first time slot. The second station receives the second communication and the power commands. A power level of the second communication as received is measured. A path loss estimate is determined based on in part the measured received second communication power level and the first communication transmission power level. The second station transmits a second communication to the first station in a second time slot. The second communication transmission power level is set based on in part the path loss estimate weighted by a factor and the power commands. The factor is a function of a time separation of the first and second time slots.

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COMBINED CLOSED LOOP/OPEN LOOP POWER CONTROL IN A TIME DIVISION DUPLEX COMMUNICATION SYSTEM

BACKGROUND

This invention generally relates to spread spectrum time division duplex (TDD) communication systems. More particularly, the present invention relates to a system and method for controlling transmission power within TDD communication systems.

Figure 1 depicts a wireless spread spectrum time division duplex (TDD) communication system. The system has a plurality of base stations $\mathbf{30_1}$-$\mathbf{30_7}$. Each base station $\mathbf{30_1}$ communicates with user equipments (UEs) $\mathbf{32_1}$-$\mathbf{32_3}$ in its operating area. Communications transmitted from a base station $\mathbf{30_1}$ to a UE $\mathbf{32_1}$ are referred to as downlink communications and communications transmitted from a UE $\mathbf{32_1}$ to a base station $\mathbf{30_1}$ are referred to as uplink communications.

In addition to communicating over different frequency spectrums, spread spectrum TDD systems carry multiple communications over the same spectrum. The multiple signals are distinguished by their respective chip code sequences (codes). Also, to more efficiently use the spread spectrum, TDD systems as illustrated in **Figure 2** use repeating frames **34** divided into a number of time slots $\mathbf{36_1}$-$\mathbf{36_{n,}}$, such as fifteen time slots. In such systems, a communication is sent in selected time slots $\mathbf{36_1}$-$\mathbf{36_n}$ using selected codes. Accordingly, one frame **34** is capable of carrying multiple communications distinguished by both time slot $\mathbf{36_1}$-$\mathbf{36_n}$ and code. The

combination of a single code in a single time slot is referred to as a resource unit. Based on the bandwidth required to support a communication, one or multiple resource units are assigned to that communication.

Most TDD systems adaptively control transmission power levels. In a TDD system, many communications may share the same time slot and spectrum. When a UE 32_1 or base station 30_1 is receiving a specific communication, all the other communications using the same time slot and spectrum cause interference to the specific communication. Increasing the transmission power level of one communication degrades the signal quality of all other communications within that time slot and spectrum. However, reducing the transmission power level too far results in undesirable signal to noise ratios (SNRs) and bit error rates (BERs) at the receivers. To maintain both the signal quality of communications and low transmission power levels, transmission power control is used.

One approach to control transmission power levels is open loop power control. In open loop power control, typically a base station 30_1 transmits to a UE 32_1 a reference downlink communication and the transmission power level of that communication. The UE 32_1 receives the reference communication and measures its received power level. By subtracting the received power level from the transmission power level, a pathloss for the reference communication is determined. To determine a transmission power level for the uplink, the downlink pathloss is added to a desired received power level at the base station 30_1. The UE's transmission power level is set to the determined uplink transmission power level.

Another approach to control transmission power level is closed loop power control. In closed loop power control, typically the base station $\mathbf{30_1}$ determines the signal to interference ratio (SIR) of a communication received from the UE $\mathbf{32_1}$. The determined SIR is compared to a target SIR (SIR_{TARGET}). Based on the comparison, the base station $\mathbf{30_1}$ transmits a power command, b_{TPC}. After receiving the power command, the UE $\mathbf{32_1}$ increases or decreases its transmission power level based on the received power command.

Both closed loop and open loop power control have disadvantages. Under certain conditions, the performance of closed loop systems degrades. For instance, if communications sent between a UE and a base station are in a highly dynamic environment, such as due to the UE moving, such systems may not be able to adapt fast enough to compensate for the changes. The update rate of closed loop power control in TDD is 100 cycles per second which is not sufficient for fast fading channels. Open loop power control is sensitive to uncertainties in the uplink and downlink gain chains and interference levels.

One approach to combining closed loop and open loop power control was proposed by the Association of Radio Industries and Business (ARIB) and uses **Equations 1**, **2**, and **3**.

$$T_{UE} = P_{BS}(n) + L \qquad \textbf{Equation 1}$$

$$P_{BS}(n) = P_{BS}(n-1) + b_{TPC}\,\Delta_{TPC} \qquad \textbf{Equation 2}$$

$$b_{TPC} = \begin{cases} 1: \text{if } SIR_{BS} < SIR_{TARGET} \\ -1: \text{if } SIR_{BS} > SIR_{TARGET} \end{cases} \qquad \textbf{Equation 3}$$

T_{UE} is the determined transmission power level of the UE 32_1. L is the estimated downlink pathloss. $P_{BS}(n)$ is the desired received power level of the base station 30_1 as adjusted by **Equation 2**. For each received power command, b_{TPC}, the desired received power level is increased or decreased by Δ_{TPC}. Δ_{TPC} is typically one decibel (dB). The power command, b_{TPC}, is one, when the SIR of the UE's uplink communication as measured at the base station **30**, SIR_{BS}, is less than a target SIR, SIR_{TARGET}. Conversely, the power command is minus one, when SIR_{BS} is larger than SIR_{TARGET}.

Under certain conditions, the performance of these systems degrades. For instance, if communications sent between a UE **32** and a base station **30** are in a highly dynamic environment, such as due to the UE **32** moving, the path loss estimate for open loop severely degrades the overall system's performance. Accordingly, there is a need for alternate approaches to maintain signal quality and low transmission power levels for all environments and scenarios.

SUMMARY

Combined closed loop/open loop power control controls transmission power levels in a spread spectrum time division duplex communication station. A first communication station receives communications from a second communication station. The first station transmits power commands based on in part a reception quality of the received communications. The first station transmits a second communication having a transmission power level in a first time slot. The second

station receives the second communication and the power commands. A power level of the second communication as received is measured. A path loss estimate is determined based on in part the measured received second communication power level and the first communication transmission power level. The second station transmits a second communication to the first station in a second time slot. The second communication transmission power level is set based on in part the path loss estimate weighted by a factor and the power commands. The factor is a function of a time separation of the first and second time slots.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 illustrates a prior art TDD system.

Figure 2 illustrates time slots in repeating frames of a TDD system.

Figure 3 is a flow chart of combine closed loop/open loop power control.

Figure 4 is a diagram of components of two communication stations using combined closed loop/open loop power control.

Figures 5-10 depict graphs of the performance of a closed loop, ARIB's proposal and two (2) schemes of combined closed loop/open loop power control.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

The preferred embodiments will be described with reference to the drawing figures where like numerals represent like elements throughout. Combined closed loop/open loop power control will be explained using the flow chart of **Figure 3** and

the components of two simplified communication stations **50, 52** as shown in **Figure 4**. For the following discussion, the communication station having its transmitter's power controlled is referred to as the transmitting station **52** and the communication station receiving power controlled communications is referred to as the receiving station **50**. Since combined closed loop/open loop power control may be used for uplink, downlink or both types of communications, the transmitter having its power controlled may be located at a base station 30_1, UE 32_1 or both. Accordingly, if both uplink and downlink power control are used, the receiving and transmitting station's components are located at both the base station 30_1 and UE 32_1.

The receiving station **50** receives various radio frequency signals including communications from the transmitting station **52** using an antenna **56**, or alternately, an antenna array. The received signals are passed through an isolator **60** to a demodulator **68** to produce a baseband signal. The baseband signal is processed, such as by a channel estimation device **96** and a data estimation device **98**, in the time slots and with the appropriate codes assigned to the transmitting station's communication. The channel estimation device **96** commonly uses the training sequence component in the baseband signal to provide channel information, such as channel impulse responses. The channel information is used by the data estimation device **98**, the interference measurement device **90**, the signal power measurement device **92** and the transmit power calculation device **94**. The data estimation device **98** recovers data from the channel by estimating soft symbols using the channel information. Using the soft symbols and channel information, the transmit power

calculation device **94** controls the receiving station's transmission power level by controlling the gain of an amplifier **76**.

The signal power measurement device **92** uses either the soft symbols or the channel information, or both, to determine the received signal power of the communication in decibels (dB). The interference measurement device **90** determines the interference level in dB, I_{RS}, within the channel, based on either the channel information, or the soft symbols generated by the data estimation device **102**, or both.

The closed loop power command generator **88** uses the measured communication's received power level and the interference level, I_{RS}, to determine the Signal to Interference Ratio (SIR) of the received communication. Based on a comparison of the determined SIR with a target SIR (SIR_{TARGET}), a closed loop power command is generated, b_{TPC}, such as a power command bit, b_{TPC}, **step 38**. Alternately, the power command may be based on any quality measurement of the received signal.

For use in estimating the path loss between the receiving and transmitting stations **50**, **52** and sending data, the receiving station **50** sends a communication to the transmitting station **58, step 40**. The communication may be sent on any one of various channels. Typically, in a TDD system, the channels used for estimating path loss are referred to as reference channels, although other channels may be used. If the receiving station **50** is a base station 30_1, the communication is preferably sent over a downlink common channel or a common control physical channel (CCPCH).

Data to be communicated to the transmitting station **52** over the reference channel is referred to as reference channel data. The reference data may include, as shown, the interference level, I_{RS}, multiplexed with other reference data, such as the transmission power level of the reference channel, T_{RS}. The interference level, I_{RS}, and reference channel power level, T_{RS}, may be sent in other channels, such as a signaling channel, **step 40**. The closed loop power control command, b_{TPC}, is typically sent in a dedicated channel, dedicated to the communication between the receiving station **50** and transmitting station **52**.

The reference channel data is generated by a reference channel data generator **86**. The reference data is assigned one or multiple resource units based on the communication's bandwidth requirements. A spreading and training sequence insertion device **82** spreads the reference channel data and makes the spread reference data time-multiplexed with a training sequence in the appropriate time slots and codes of the assigned resource units. The resulting sequence is referred to as a communication burst. The communication burst is subsequently amplified by an amplifier **78**. The amplified communication burst may be summed by a sum device **72** with any other communication burst created through devices, such as a data generator **84**, spreading and training sequence insertion device **80** and amplifier **76**.

The summed communication bursts are modulated by a modulator **64**. The modulated signal is passed through an isolator **60** and radiated by an antenna **56** as shown or, alternately, through an antenna array. The radiated signal is passed through a wireless radio channel **54** to an antenna **58** of the transmitting station **52**.

The type of modulation used for the transmitted communication can be any of the those known to those skilled in the art, such as direct phase shift keying (DPSK) or quadrature phase shift keying (QPSK).

The antenna **58** or, alternately, antenna array of the transmitting station **52** receives various radio frequency signals. The received signals are passed through an isolator **62** to a demodulator **66** to produce a baseband signal. The baseband signal is processed, such as by a channel estimation device **100** and a data estimation device **102**, in the time slots and with the appropriate codes assigned to the communication burst of the receiving station **50**. The channel estimation device **100** commonly uses the training sequence component in the baseband signal to provide channel information, such as channel impulse responses. The channel information is used by the data estimation device **102** and a power measurement device **110**.

The power level of the processed communication corresponding to the reference channel, R_{TS}, is measured by the power measurement device **110** and sent to a pathloss estimation device **112, step 42**. Both the channel estimation device **100** and the data estimation device **102** are capable of separating the reference channel from all other channels. If an automatic gain control device or amplifier is used for processing the received signals, the measured power level is adjusted to correct for the gain of these devices at either the power measurement device **110** or the pathloss estimation device **112**. The power measurement device **110** is a component of the combined closed loop/open loop controller **108**. As illustrated in **Figure 4**, the combined closed loop/open loop power controller **108** consists of the power

measurement device **110**, pathloss estimation device **112**, quality measurement device **114**, and transmit power calculation device **116**.

To determine the path loss, L, the transmitting station **52** also requires the communication's transmitted power level, T_{RS}. The transmitted power level, T_{RS}, may be sent along with the communication's data or in a signaling channel. If the power level, T_{RS}, is sent along with the communication's data, the data estimation device **102** interprets the power level and sends the interpreted power level to the pathloss estimation device **112**. If the receiving station **50** is a base station $\mathbf{30_1}$, preferably the transmitted power level, T_{RS}, is sent via the broadcast channel (BCH) from the base station $\mathbf{30_1}$. By subtracting the received communication's power level, R_{TS} in dB, from the sent communication's transmitted power level, T_{RS} in dB, the pathloss estimation device **112** estimates the path loss, L, between the two stations **50**, **52**, **step 42**. In certain situations, instead of transmitting the transmitted power level, T_{RS}, the receiving station **50** may transmit a reference for the transmitted power level. In that case, the pathloss estimation device **112** provides reference levels for the path loss, L.

If a time delay exists between the estimated path loss and the transmitted communication, the path loss experienced by the transmitted communication may differ from the calculated loss. In TDD systems where communications are sent in differing time slots $\mathbf{36_1}$-$\mathbf{36_n}$, the time slot delay between received and transmitted communications may degrade the performance of an open loop power control system. Combined closed loop/open loop power control utilizes both closed loop

and open loop power control aspects. If the quality of the path loss measurement is high, the system primarily acts as an open loop system. If the quality of the path loss measurement is low, the system primarily acts as a closed loop system. To combine the two power control aspects, the system weights the open loop aspect based on the quality of the path loss measurement.

A quality measurement device **114** in a weighted open loop power controller **108** determines the quality of the estimated path loss, **step 46**. The quality may be determined using the channel information generated by the channel estimation device **100**, the soft symbols generated by the data estimation device **102** or other quality measurement techniques. The estimated path loss quality is used to weight the path loss estimate by the transmit power calculation device **116**. If the power command, b_{TPC}, was sent in the communication's data, the data estimation device **102** interprets the closed loop power command, b_{TPC}. Using the closed loop power command, b_{TPC}, and the weighted path loss, the transmit power calculation device **116** sets the transmit power level of the receiving station **50**, **step 48**.

The following is one of the preferred combined closed loop/open loop power control algorithms. The transmitting station's power level in decibels, P_{TS}, is determined using **Equations 4** and **6**.

$$P_{TS} = P_0 + G(n) + \alpha L \qquad \textbf{Equation 4}$$

P_0 is the power level that the receiving station **50** desires to receive the transmitting station's communication in dB. P_0 is determined by the desired SIR at the receiving station **50**, SIR_{TARGET}, and the interference level, I_{RS}, at the receiving

station **50** using **Equation 5**.

$$P_0 = SIR_{TARGET} + I_{RS} \qquad \textbf{Equation 5}$$

I_{RS} is either signaled or broadcasted from the receiving station **50** to the transmitting station **52**. For downlink power control, SIR_{TARGET} is known at the transmitting station **52**. For uplink power control, SIR_{TARGET} is signaled from the receiving station **50** to the transmitting station **52**. G(n) is the closed loop power control factor. **Equation 6** is one equation for determining G(n).

$$G(n) = G(n-1) + b_{TPC}\,\Delta_{TPC} \qquad \textbf{Equation 6}$$

G(n-1) is the previous closed loop power control factor. The power command, b_{TPC}, for use in **Equation 6** is either +1 or -1. One technique for determining the power command, b_{TPC}, is **Equation 3**. The power command, b_{TPC}, is typically updated at a rate of 100 ms in a TDD system, although other update rates may be used. Δ_{TPC} is the change in power level. The change in power level is typically 1 dB although other values may be used. As a result, the closed loop factor increases by 1 dB if b_{TPC} is +1 and decreases by 1 dB if b_{TPC} is -1.

The weighting value, α, is determined by the quality measurement device **114**. α is a measure of the quality of the estimated path loss and is, preferably, based on the number of time slots, D, between the time slot of the last path loss estimate and the first time slot of the communication transmitted by the transmitting station **52**. The value of α is from zero to one. Generally, if the time difference, D, between the time slots is small, the recent path loss estimate will be fairly accurate and α is set at a value close to one. By contrast, if the time difference is large, the path loss

estimate may not be accurate and the closed loop aspect is most likely more accurate. Accordingly, α is set at a value closer to zero.

Equation 7 is one equation for determining α, although others may be used.

$$\alpha = 1 - (D - 1)/D_{max} \qquad \textbf{Equation 7}$$

D_{max} is the maximum possible delay. A typical value for a frame having fifteen time slots is six. If the delay is D_{max} or greater, α approaches zero. Using the calculated transmit power level, P_{TS}, determined by a transmit power calculation device **116**, the combined closed loop/open loop power controller **108** sets the transmit power of the transmitted communication.

Data to be transmitted in a communication from the transmitting station **52** is produced by a data generator **106**. The communication data is spread and time-multiplexed with a training sequence by the spreading and training sequence insertion device **104** in the appropriate time slots and codes of the assigned resource units producing a communication burst. The spread signal is amplified by the amplifier **74** and modulated by the modulator **70** to radio frequency.

The combined closed loop/open loop power controller **108** controls the gain of the amplifier **74** to achieve the determined transmit power level, P_{TS}, for the communication. The power controlled communication is passed through the isolator **62** and radiated by the antenna **58**.

Equations 8 and **9** are another preferred combined closed loop/open loop power control algorithm.

$$P_{TS} = P_0 + K(n) \qquad \textbf{Equation 8}$$

$$K(n) = K(n-1) + b_{TPC}\,\Delta_{TPC} + \alpha L \qquad \textbf{Equation 9}$$

K(n) is the combined closed loop/open loop factor. As shown, this factor includes both the closed loop and open loop power control aspects. **Equations 4** and **5** segregate the two aspects.

Although the two above algorithms only weighted the open loop factor, the weighting may be applied to the closed loop factor or both the open and closed loop factors. Under certain conditions, the network operator may desire to use solely open loop or solely closed loop power control. For example, the operator may use solely closed loop power control by setting α to zero.

Figures 5-10 depict graphs **118-128** illustrating the performance of a combined closed-loop/open-loop power control system. These graphs **118-128** depict the results of simulations comparing the performance of the ARIB proposed system, a closed loop, a combined open loop/closed loop system using **Equations 4** and **6** (scheme I) and a combined system using **Equations 8** and **9** (scheme II). The simulations were performed at the symbol rate. A spreading factor of sixteen was used for both the uplink and downlink channels. The uplink and downlink channels are International Telecommunication Union (ITU) Channel model [ITU-R M.1225, vehicular, type B]. Additive noises were simulated as being independent of white Gaussian noises with unity variance. The path loss is estimated at the transmitting station **52** which is a UE $\mathbf{32_1}$ and in particular a mobile station. The BCH channel was used for the path loss estimate. The path loss was estimated two times per frame at a rate of 200 cycles per second. The receiving station **50**, which

was a base station 30_1, sent the BCH transmission power level over the BCH. RAKE combining was used for both the UE 32_1 and base station 30_1. Antenna diversity combining was used at the base station 30_1.

Graphs **118, 122, 126** depict the standard deviation of the received signal to noise ratio (SNR) at the base station 30_1 of the UE's power controlled communication as a function of the time slot delay, D. Graphs **120, 124, 128** depict the normalized bias of the received SNR as a function of the delay, D. The normalization was performed with respect to the desired SNR. Each point in the graphs **118-128** represents the average of 3000 Monte-Carlo runs.

Graphs **118, 120** depict the results for an α set at one. For low time slot delays ($D<4$), scheme I and II outperform closed loop power control. For larger delays ($D\geq 4$), closed loop outperforms both scheme I and II which demonstrates the importance of weighting the open loop and closed loop aspects.

Graphs **122, 124** depict the results for an α set at 0.5. As shown, for all delays excluding the maximum, schemes I and II outperform closed loop power control. The ARIB proposal only outperforms the others at the lowest delay ($D=1$).

Graphs **126, 128** depict the results for an α set using **Equation 7** with D_{max} equal to six. As shown, schemes I and II outperform both closed loop and the ARIB proposal at all delays, D.

* * *

CLAIMS

1. A method for controlling transmission power levels in a spread spectrum time division duplex communication system having frames with time slots for communication, the method comprising:

receiving at a first communication station communications from a second communication station and transmitting from the first station power commands based on in part a reception quality of the received communications;

transmitting from the first communication station a first communication having a transmission power level in a first time slot;

receiving at the second communication station the first communication and the power commands;

measuring a power level of the first communication as received;

determining a pathloss estimate based on in part the measured received first communication power level and the first communication transmission power level; and

setting a transmission power level for a second communication in a second time slot from the second station to the first station based on in part the pathloss estimate weighted by a quality factor and the power commands, wherein the quality factor is a function of a time separation of the first and second time slots.

2. The method of claim 1 further comprising:

determining a quality, α, of the pathloss estimate based on in part a number

of time slots, D, between the first and second time slot; and

wherein the quality factor is α.

3. The method of claim 1 wherein a maximum time slot delay is D_{max} and the determined quality, α, is determined by

$\alpha = 1 - (D-1) / D_{max}$.

4. The method of claim 1 wherein the set transmission power level is based on in part a desired received power level at the first station, a closed loop factor and an open loop factor; wherein the closed loop factor is based on in part the received power commands and the open loop factor is based on in part the pathloss estimate weighted by the quality factor.

5. The method of claim 1 wherein the set transmission power level is based on in part a desired received power level at the first station and a combined closed loop/open loop factor; wherein the combined closed loop/open loop factor is based on in part the received power commands and the pathloss estimate weighted by the quality factor.

6. The method of claim 4 wherein the closed loop factor is updated for each received power command.

7. The method of claim 5 wherein the combined factor is updated for each received power command.

8. The method of claim 4 wherein the desired received power level is based on in part a target signal to interference ratio and a measured interference level at the first station.

9. The method of claim 5 wherein the desired received power level is based on in part a target signal to interference ratio and a measured interference level at the first station.

10. The method of claim 1 wherein the first station is a base station and the second station is a user equipment.

11. The method of claim 1 wherein the first station is a user equipment and the second station is a base station.

12. A spread spectrum time division duplex communication system having a first and second communication station, the system using frames with time slots for communication, the system comprising:

the first station comprising:

means for receiving communications from the second communication

station and transmitting power commands based on in part a reception quality of the received communications; and

means for transmitting a first communication having a transmission power level in a first time slot; and

the second station comprising:

means for receiving the first communication and the power commands;

means for measuring a power level of the first communication as received;

means for determining a pathloss estimate based on in part the measured received first communication power level and the first communication transmission power level; and

means for setting a transmission power level for a second communication in a second time slot from the second station to the first station based on in part the pathloss estimate weighted by a quality factor and the power commands, wherein the quality factor is a function of a time separation of the first and second time slots.

13. The system of claim 12 wherein:

the second station further comprises means for determining a quality, α, of the pathloss estimate based on in part a number of time slots, D, between the first and second time slot; and

the quality factor is α.

14. The system of claim 12 wherein a maximum time slot delay is D_{max} and the determined quality, α, is determined by

$\alpha = 1 - (D-1) / D_{max}$.

15. The system of claim 1 wherein the setting means sets the transmission power level based on in part a desired received power level at the first station, a closed loop factor and an open loop factor, the closed loop factor is based on in part the received power commands and the open loop factor is based on in part the pathloss estimate weighted by the quality factor.

16. The system of claim 1 wherein the setting means sets the transmission power level based on in part a desired received power level at the first station and a combined closed loop/open loop factor, the combined closed loop/open loop factor is based on in part the received power commands and the path loss estimate weighted by the quality factor.

17. The system of claim 15 wherein the closed loop factor is updated for each received power command.

18. The system of claim 16 wherein the combined factor is updated for each received power command.

19. The system of claim 15 wherein the desired received power level is based on in part a target signal to interference ratio and a measured interference level at the first station.

20. The system of claim 16 wherein the desired received power level is based on in part a target signal to interference ratio and a measured interference level at the first station.

21. The system of claim 12 wherein the first station is a base station and the second station is a user equipment.

22. The system of claim 12 wherein the first station is a user equipment and the second station is a base station.

23. A communication station having its transmission power level controlled in a spread spectrum time division duplex communication system, the system using frames with time slots for communication and having a second communication station transmitting a first communication in a first time slot and power commands, the communication station comprising:

at least one antenna for receiving the first communication and the power commands and transmitting an amplified second communication in a second time slot;

a channel estimation device having an input configured to receive the received first communication for producing channel information;

a data estimation device having inputs configured to receive the received first communication, the power commands and the channel information for producing soft symbols and recovering the power commands;

a power measurement device having an input configured to receive the channel information for producing a measurement of a received power level for producing a pathloss estimate for the first communication;

a quality measurement device for producing a quality measurement based at least in part upon a time separation of the first time slot and a second time slot;

a transmit power calculation device having inputs configured to receive the pathloss estimation, the recovered power commands and the quality measurement for producing a power control signal based on in part the pathloss estimate weighted by the quality measurement and the recovered power commands; and

an amplifier having inputs configured to receive the power control signal and a second communication to be transmitted in the second time slot for amplifying the second communication in response to the power control signal to produce the amplified second communication.

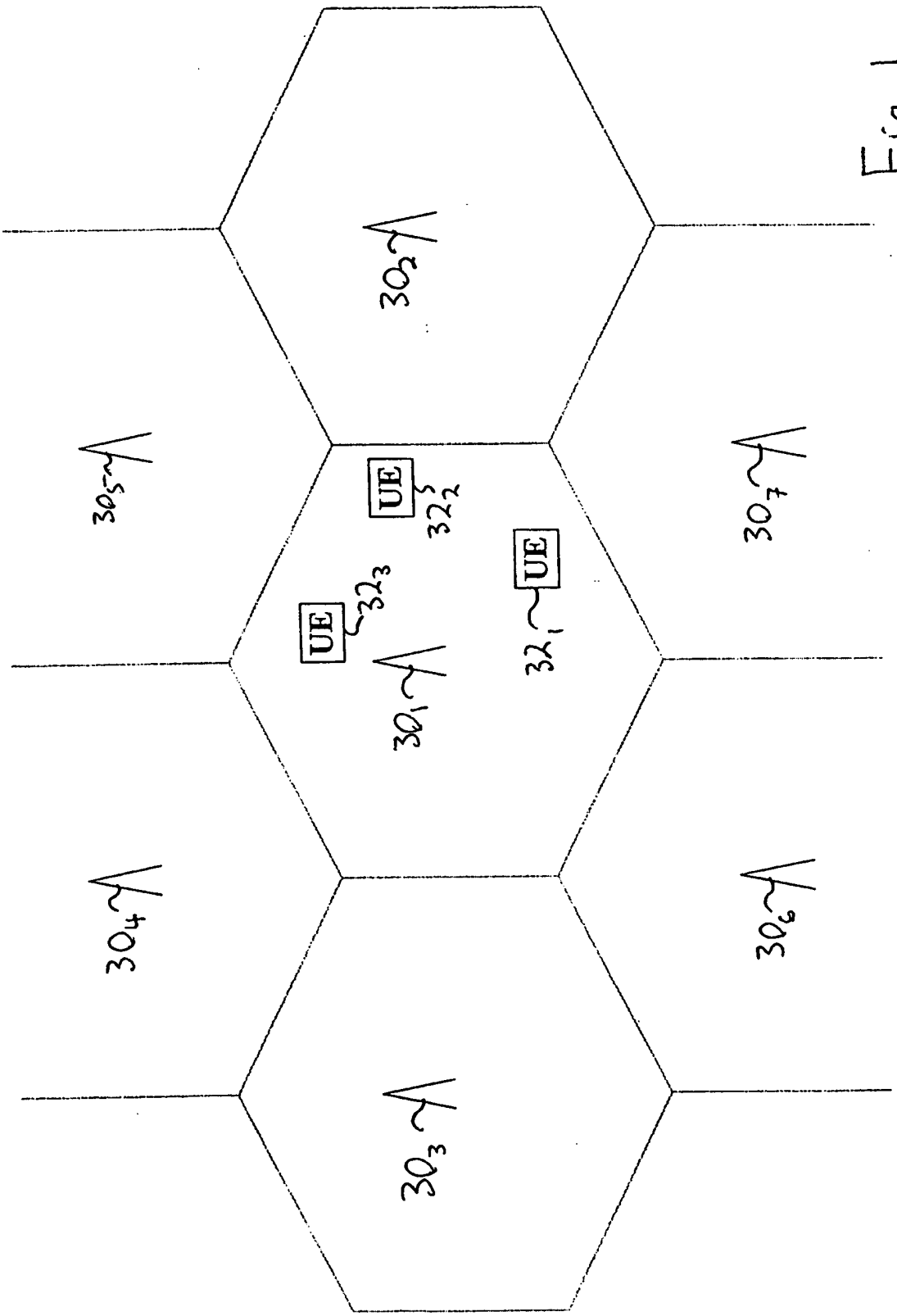

Fig. 1

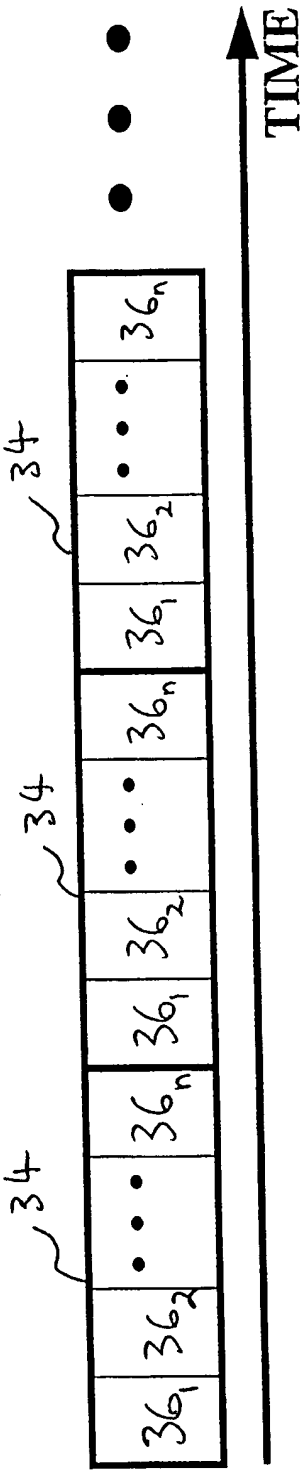

Fig. 2

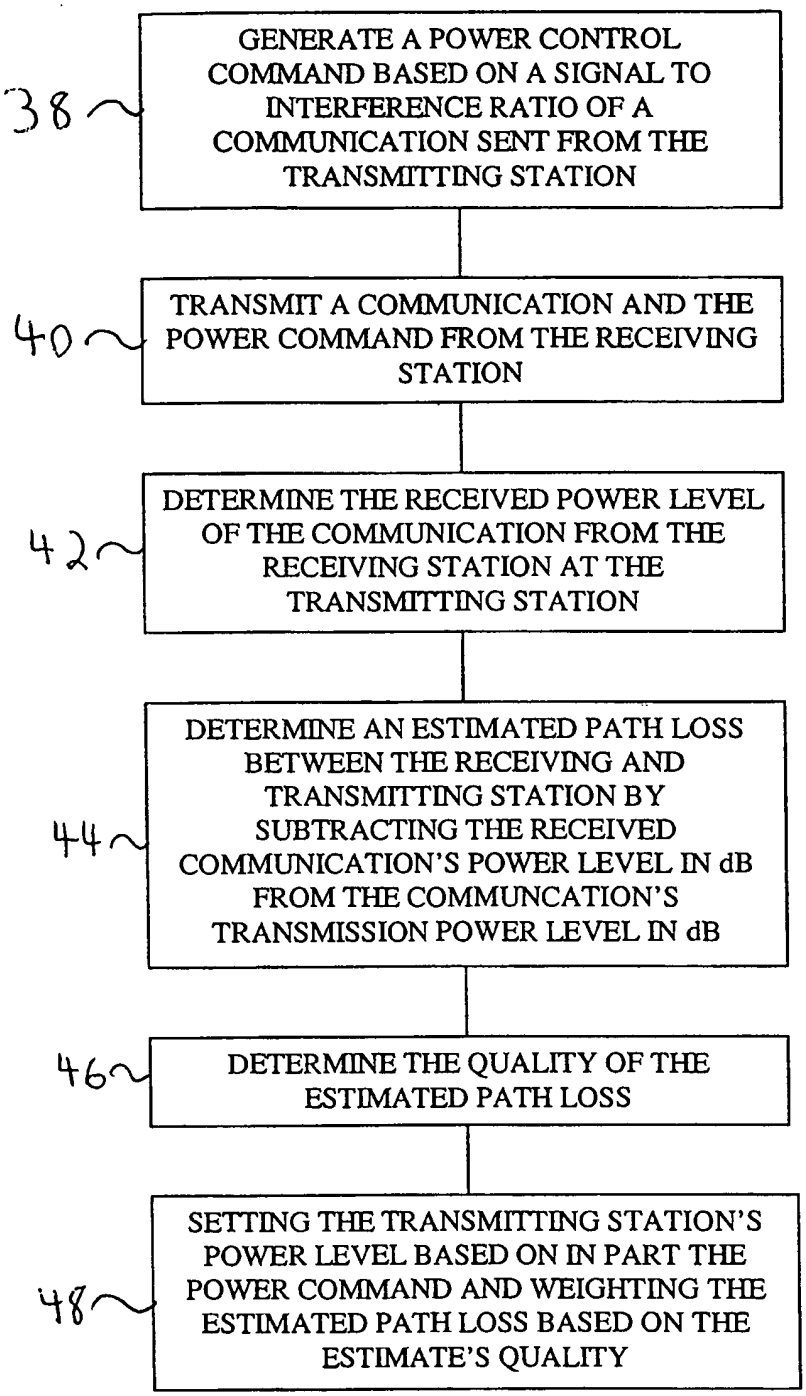
38
GENERATE A POWER CONTROL COMMAND BASED ON A SIGNAL TO INTERFERENCE RATIO OF A COMMUNICATION SENT FROM THE TRANSMITTING STATION
40
TRANSMIT A COMMUNICATION AND THE POWER COMMAND FROM THE RECEIVING STATION
42
DETERMINE THE RECEIVED POWER LEVEL OF THE COMMUNICATION FROM THE RECEIVING STATION AT THE TRANSMITTING STATION
44
DETERMINE AN ESTIMATED PATH LOSS BETWEEN THE RECEIVING AND TRANSMITTING STATION BY SUBTRACTING THE RECEIVED COMMUNICATION'S POWER LEVEL IN dB FROM THE COMMUNCATION'S TRANSMISSION POWER LEVEL IN dB
46
DETERMINE THE QUALITY OF THE ESTIMATED PATH LOSS
48
SETTING THE TRANSMITTING STATION'S POWER LEVEL BASED ON IN PART THE POWER COMMAND AND WEIGHTING THE ESTIMATED PATH LOSS BASED ON THE ESTIMATE'S QUALITY

Fig. 3

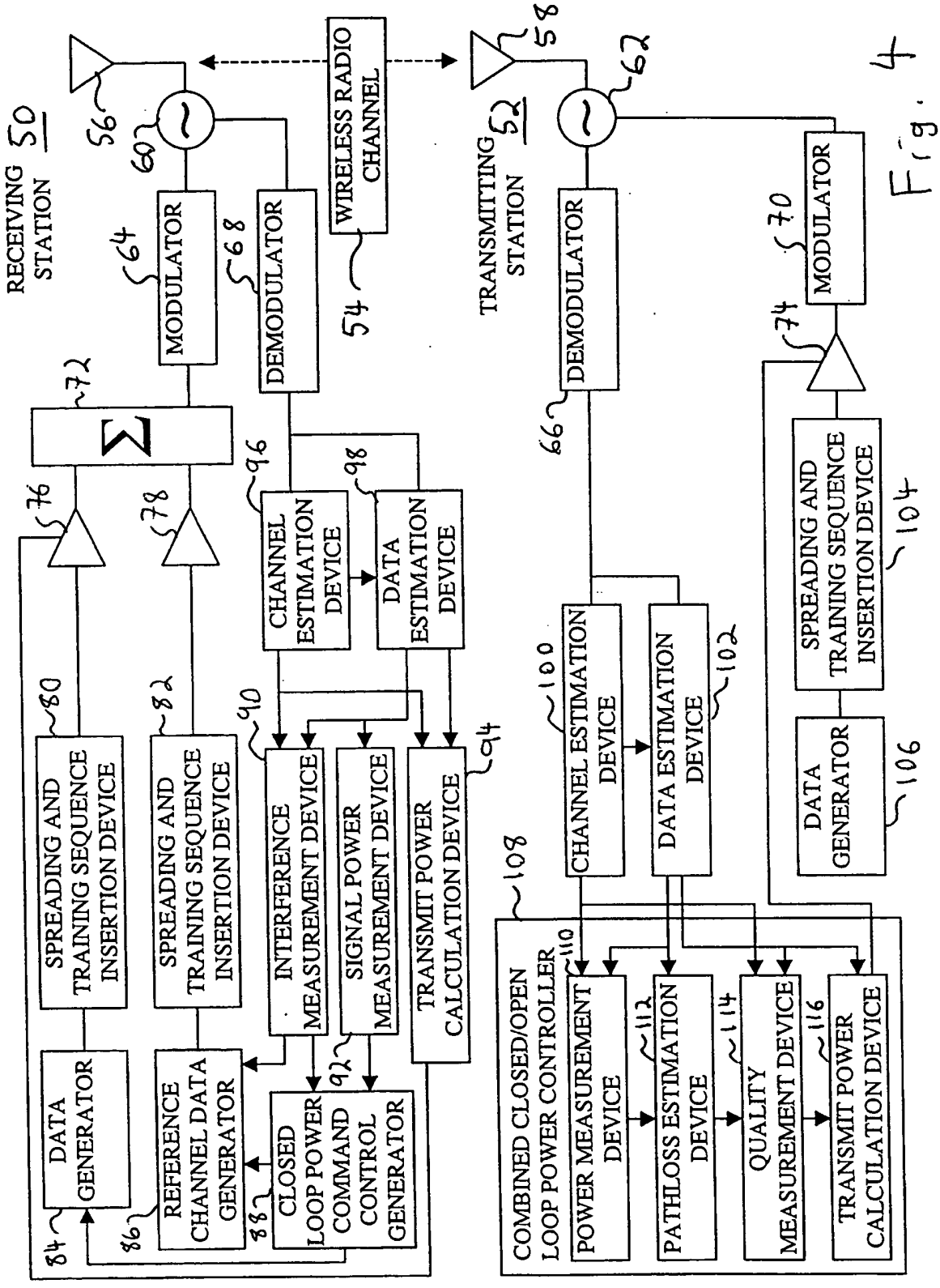
RECEIVING STATION 50
TRANSMITTING STATION 52
WIRELESS RADIO CHANNEL
54
56
58
60
62
64
MODULATOR
66
DEMODULATOR
68
DEMODULATOR
70
MODULATOR
72
Σ
74
76
78
80
SPREADING AND TRAINING SEQUENCE INSERTION DEVICE
82
SPREADING AND TRAINING SEQUENCE INSERTION DEVICE
84
DATA GENERATOR
86
REFERENCE CHANNEL DATA GENERATOR
88
CLOSED LOOP POWER COMMAND CONTROL GENERATOR
90
INTERFERENCE MEASUREMENT DEVICE
92
SIGNAL POWER MEASUREMENT DEVICE
94
TRANSMIT POWER CALCULATION DEVICE
96
CHANNEL ESTIMATION DEVICE
98
DATA ESTIMATION DEVICE
100
CHANNEL ESTIMATION DEVICE
102
DATA ESTIMATION DEVICE
104
SPREADING AND TRAINING SEQUENCE INSERTION DEVICE
106
DATA GENERATOR
108
COMBINED CLOSED/OPEN LOOP POWER CONTROLLER
110
POWER MEASUREMENT DEVICE
112
PATHLOSS ESTIMATION DEVICE
114
QUALITY MEASUREMENT DEVICE
116
TRANSMIT POWER CALCULATION DEVICE

Fig. 4

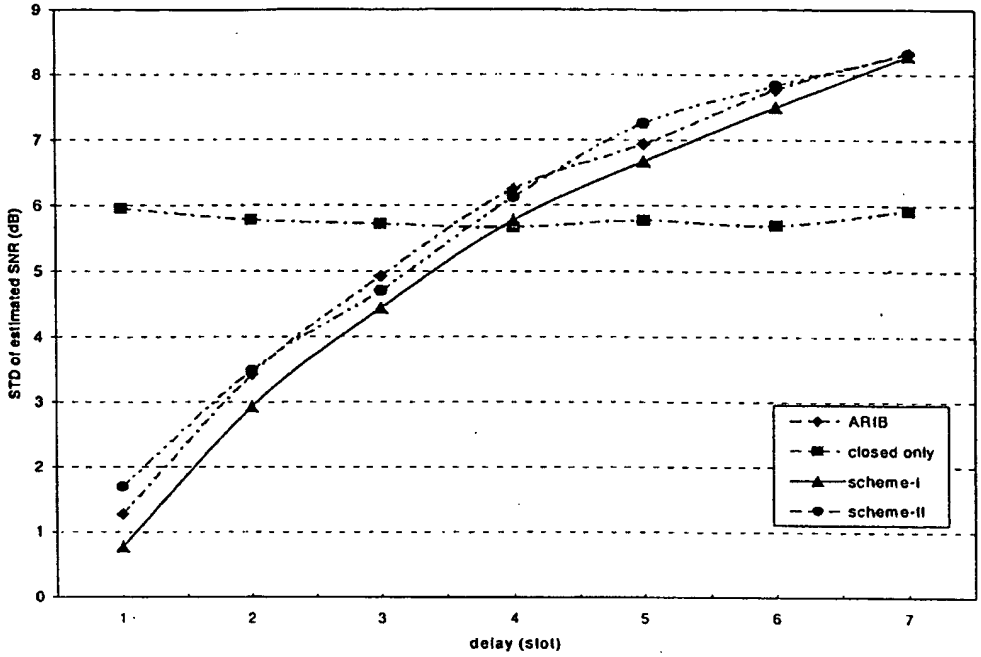
STD of estimated SNR (dB)
delay (slot)
ARIB
closed only
scheme-I
scheme-II

Fig. 5

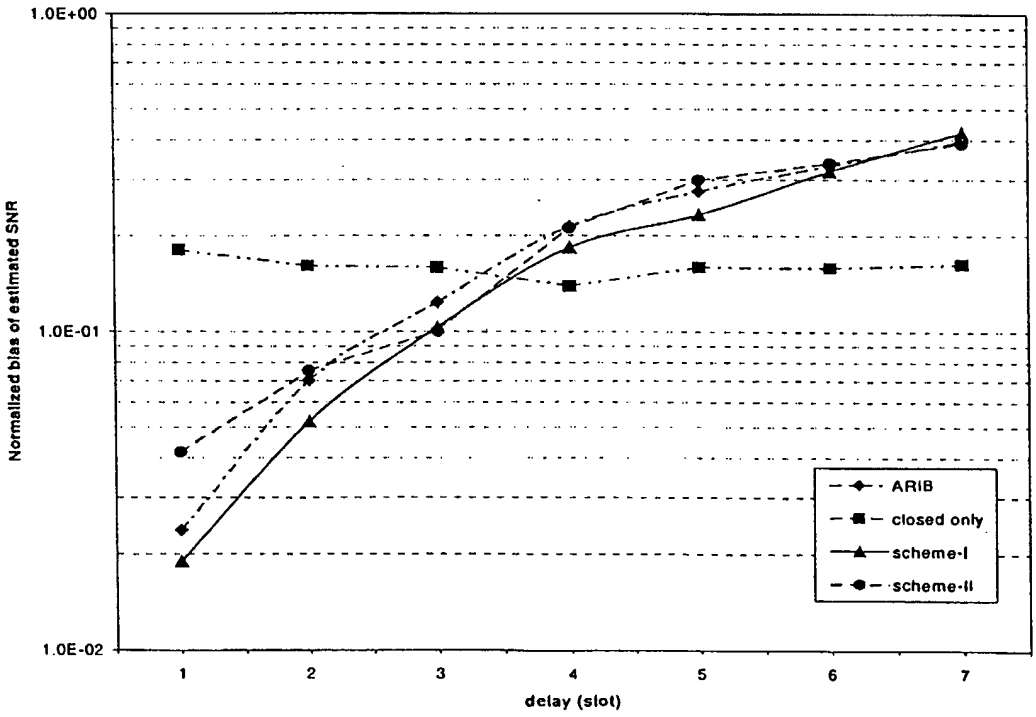
Normalized bias of estimated SNR
1.0E+00
1.0E-01
1.0E-02
delay (slot)
ARIB
closed only
scheme-I
scheme-II

Fig. 6

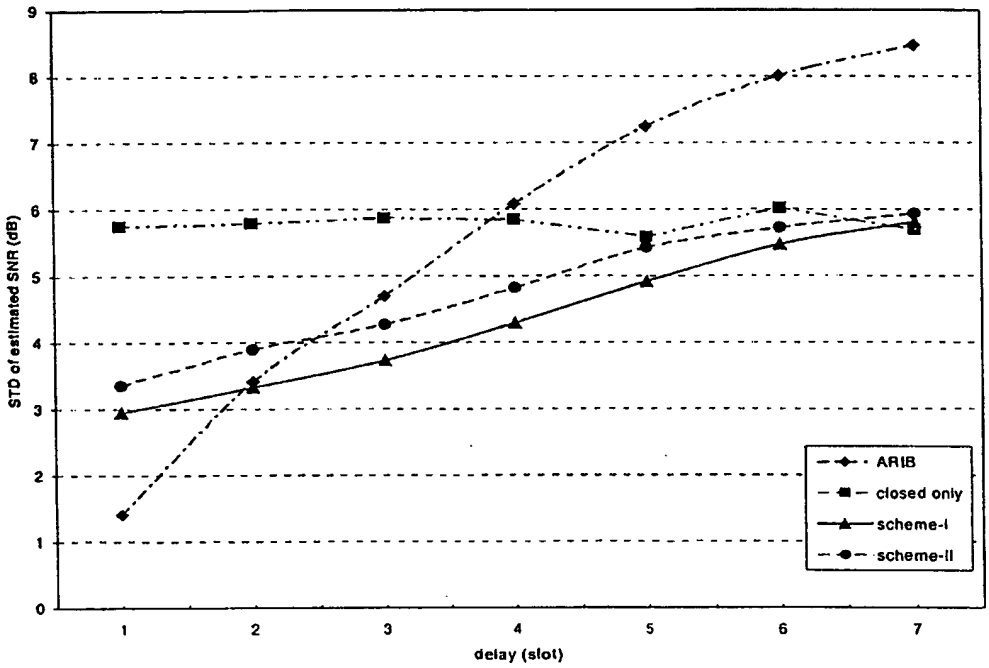
STD of estimated SNR (dB)
delay (slot)
ARIB
closed only
scheme-I
scheme-II

Fig. 7

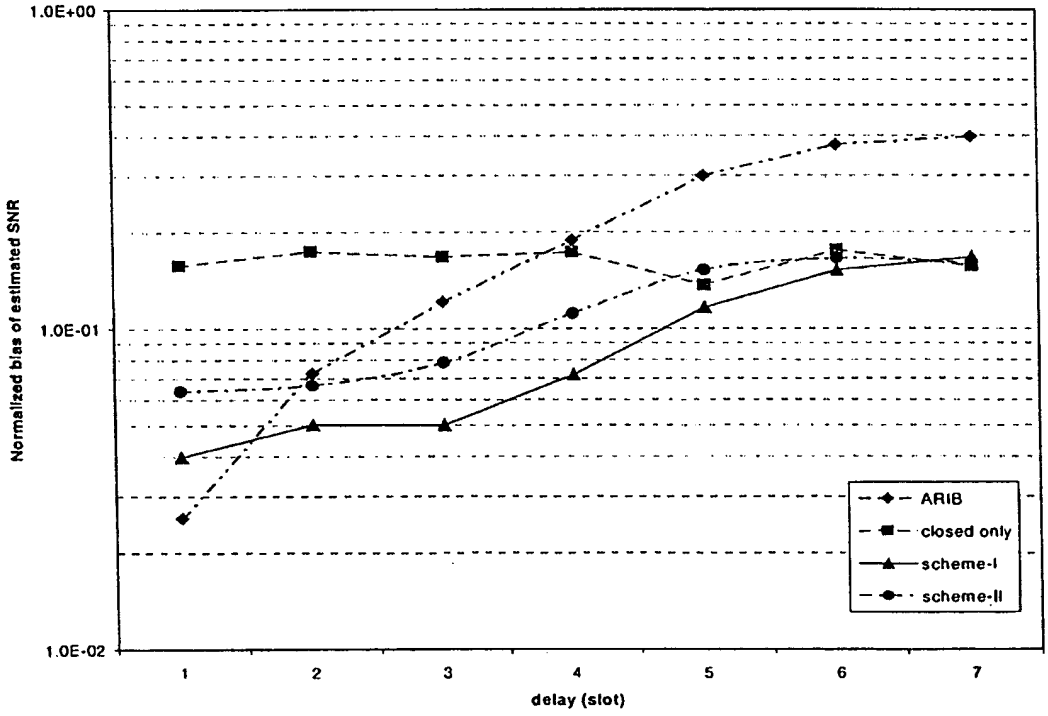
Normalized bias of estimated SNR
1.0E+00
1.0E-01
1.0E-02
delay (slot)
ARIB
closed only
scheme-I
scheme-II

Fig. 8

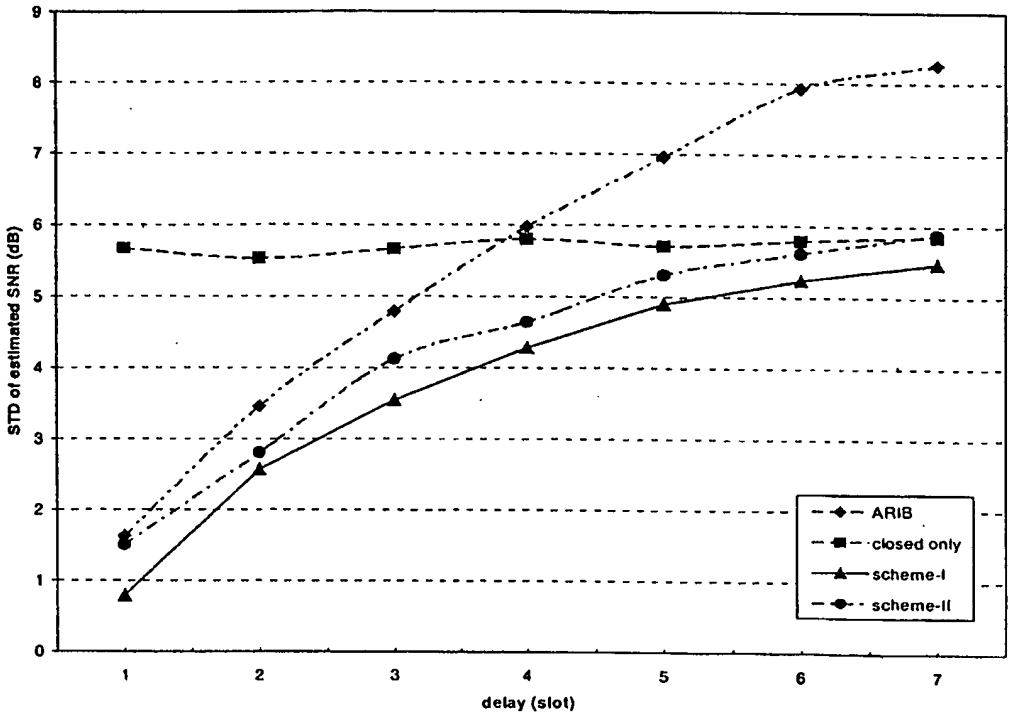
STD of estimated SNR (dB)
delay (slot)
ARIB
closed only
scheme-I
scheme-II

Fig. 9

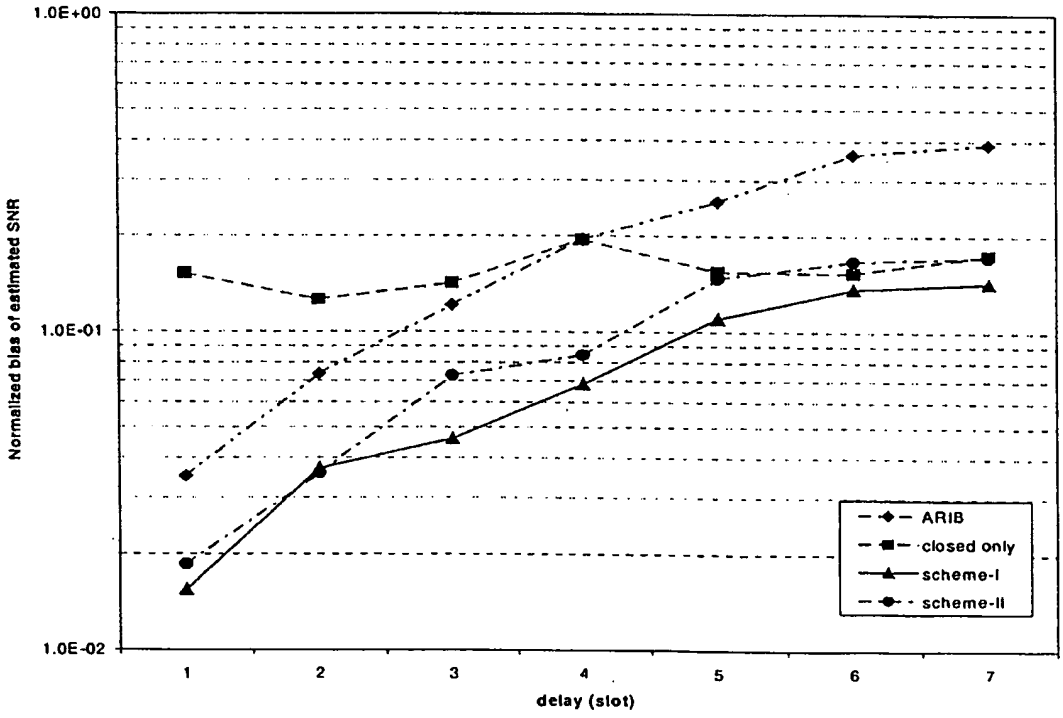
Normalized bias of estimated SNR
1.0E+00
1.0E-01
1.0E-02
delay (slot)
ARIB
closed only
scheme-I
scheme-II

Fig. 10

INTERNATIONAL SEARCH REPORT

Inter onal Application No
PCT/US 00/07476

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 H04B7/005

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 H04B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)
EPO-Internal, INSPEC

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	WO 97 49197 A (HONKASALO ZHICHUN ;NOKIA MOBILE PHONES LTD (FI); JOKINEN HARRI (FI) 24 December 1997 (1997-12-24) abstract; figure 1 page 4, line 21 -page 5, line 11 page 6, line 13 -page 7, line 3 page 7, line 18 - line 29 page 11, line 18 -page 12, line 16	1,2, 4-13, 15-23
A	EP 0 682 419 A (NIPPON TELEGRAPH & TELEPHONE) 15 November 1995 (1995-11-15) abstract; figures 4,6,7 column 8, line 13 - line 44	1,4-12, 15-23

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[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

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"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

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"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
4 July 2000	13/07/2000

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL – 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Sieben, S

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INTERNATIONAL SEARCH REPORT

Inte. ional Application No
PCT/US 00/07476

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication,where appropriate, of the relevant passages	Relevant to claim No.
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A	US 5 542 111 A (IVANOV KOLIO ET AL) 30 July 1996 (1996-07-30) abstract; figures 1,2 column 2, line 20 - line 43 column 2, line 58 - line 64 column 3, line 24 -column 4, line 61 ---	1,4-12, 15-23
A	US 5 859 838 A (SOLIMAN SAMIR S) 12 January 1999 (1999-01-12) column 5, line 4 - line 19 column 8, line 1 - line 23; figure 2 -----	1,4-12, 15-23

1

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Information on patent family members

Inter nal Application No
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